U.S. DEPARTMENT OF AGRICULTURE
AGRICULTURAL RESEARCH SERVICE

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RESEARCH REVIEW and PREVIEW CONFERENCE
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MISSION:

The mission of the NCSCRL is to develop and transfer new knowledge and technologies for sustainable agriculture in northern climatic regions that protect natural resources and the environment.

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NORTH CENTRAL SOIL CONSERVATION RESEARCH LABORATORY STAFF

Research Staff:

Alessi, R. Samuel - Soil Scientist, Ph.D. 1989, North Dakota State University. Research Interest: Systems and software development using Systems Engineering principles that integrate research knowledge into forms that are useable by farm managers and consultants.

Forcella, Frank - Research Agronomist, Ph.D. 1979, University of Oklahoma. Research Interest: Weed ecology, management, and modeling, with the goal of achieving "right-input" agriculture. Adjunct Associate Professor, Department of Agronomy & Plant Genetics, University of Minnesota.

Lindstrom, Michael J. - Soil Scientist, Ph.D. 1973, Washington State University. Research Interest: Develop soil management systems that control soil erosion while maintaining or enhancing crop production. Adjunct Research Associate, Department of Soil, Water, and Climate, University of Minnesota.

Olness, Alan E. - Soil Scientist, Ph.D. 1973, University of Minnesota. Research Interest: Soil fertility, trace element analysis of soils, pesticide chemistry in soils and efficient use of nitrogen, and general soil conservation. Adjunct Research Associate, Department of Soil, Water, and Climate, University of Minnesota.

Reicosky, Donald C. - Soil Scientist, Ph.D. 1969, University of Illinois. Research Interest: Effect of tillage and soil management practices on carbon cycling, global climate change and water use efficiency. Adjunct Professor, Department of Soil, Water, and Climate, University of Minnesota.

Sharratt, Brenton S. - Soil Scientist, Ph.D. 1984, University of Minnesota. Research Interest: Overwinter heat/water/solute transport in soils as impacted by tillage/residue management in the northern Corn Belt. Adjunct Assistant Professor, Department of Soil, Water & Climate, University of Minnesota..

Voorhees, Ward B. - Soil Scientist, Research Leader and Location Coordinator, M.S. 1969, Iowa State University. Research Interest: Soil management with special emphasis on soil compaction caused by agricultural machinery and its effects on crop growth and yield, and farming systems. Adjunct Professor, Department of Soil, Water and Climate; University of Minnesota.

Westgate, Mark E. - Plant Physiologist, Ph.D. 1984, University of Illinois. Research Interest: Physiological basis for low protein content of soybeans grown in Minnesota and

physiological basis for effect of drought on seed formation in corn. Adjunct Assistant Professor, Department of Agronomy and Plant Genetics, University of Minnesota.

Young, Robert A. (Collaborator) - Agricultural Engineer, Ph.D. 1972, South Dakota State University. Research Interest: Erosion mechanics, hydrology, and environmental quality modelling and AGNPS.

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Kennedy, Ian - Soil Scientist. Simulating overwinter movement of heat, water and solutes in seasonally frozen soil profiles.

UNIVERSITY SUPPORT STAFF:

Baker, Kevin - Assistant Scientist, AGNPS model

Barbour, Nancy - Assistant Scientist, Soybean Seed Composition

Oriade, Caleb - Senior Scientist, Bio-Economic Weed Model

Reese, Cheryl - Junior Scientist, Weed Ecology Software

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Gagner, Jill M. - Office Automation Clerk

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Wilts, Alan R. - Chemist

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AGRICULTURAL RESOURCES of the UPPER MIDWEST REGION

For purposes of this document, the Upper Midwest Region of the United States refers to the general area shown in Figure 1. It may also be referred to as the Corn Belt and the northern Great Plains. The Land Resource Regions shown were identified by the USDA-Soil Conservation Service, and delineate general soil/crop production areas.

The USDA-ARS North Central Soil Conservation Research Laboratory (NCSCRL) at Morris, Minnesota, is situated at the confluence of three of these Land Resource Regions; the Central Feed Grains and Livestock Region, the Northern Great Plains Spring Wheat Region; and the Northern Lakes State Forest and Forage Region. Because of this strategic location, the NCSCRL provides leadership for research programs over a wide range of production and environmental problems covering a wide geographic scope.

The Central Feed Grains and Livestock Region ("M") is dominated by soils developed from glacial till parent material. Native vegetation of the northwestern part of this region was generally prairie grass, while in the southeastern portion, hardwood forest dominated. Organic matter ranges generally from 3-9 percent. Precipitation ranges from 19 inches (48 cm) in the northwest to 48 inches (122 cm) in the southeast. The frost-free period ranges from 127 days in the north to 217 in the southwest. Most of the soils are subjected to freezing temperatures in the surface 12 inches (30 cm). Corn and soybean make up the largest acreage.

The climate of the Northern Lakes State Forest and Forage Region ("K") is similar to the northern portion of the Central Feed Grains and Livestock Region, but has a considerably shorter frost-free period, ranging down to 85 days in the northwestern portion. Native vegetation is mostly hardwood forests. Forage crops and dairy, along with row crops and forestry, make up the bulk of agriculture.

The Northern Great Plains Spring Wheat Region ("F") is, as the name implies, a major region for the production of spring wheat. Other important crops are barley, sunflowers, corn, soybeans, sugar beets and potatoes. Soils vary from the very flat, high clay Lacustrine areas of the Red River Valley on the east to the drier (10 inches annual precipitation) coarse soils on the west. Prairie grass was the native vegetation.

The five-state area of Minnesota, North Dakota, South Dakota, Iowa and Wisconsin produce a significant percentage of the total U.S. production of several major commodities as shown in Table 1.

One of the most valuable agricultural resources in the Upper Midwest region is the cooperative research effort of the USDA-ARS and the university state experiment stations. In addition to the land grant institutions in each state, ARS has research laboratories in each of the states shown in Figure 1, covering a range of disciplines.

The Morris area is unique in that it has the highest concentration of professional agricultural/environmental people in the state of Minnesota outside of the University of Minnesota St. Paul Campus. The NCSCRL is complemented by the West Central State Experiment Station with a staff of six scientists specializing in the disciplines of animal science and pasture/forage science. Several other governmental entities interact with the NCSCRL, including the Stevens County Farm Management Program, the federal Wetland Management District, and the University of Minnesota, Morris. The NCSCRL has a unique relationship with the Computer Science Department of the University by providing specialized applied training experiences in various aspects of software engineering. In addition, there is on-going interaction with several private sector entities, including some of the most progressive and successful farm mangers in the nation.

LABORATORY HISTORY

The USDA-ARS North Central Soil Conservation Research Laboratory at Morris, Minnesota, was officially dedicated in 1960. Before that, the staff was situated for about five years at the University of Minnesota West Central Experiment Station in Morris, and in the Soils Department at the University of Minnesota, St. Paul.

Instrumental in establishing the Laboratory in Morris was a group of enthusiastic and dedicated supporters known as the **Barnes-Aastad Soil and Water Conservation Research Association, Inc.** Barnes-Aastad is the name of a soil series commonly found in west central Minnesota. It is typical of many productive soils formed from glacial till and vegetated with prairie grasses. The Barnes-Aastad Association further showed their visionary agricultural concern by purchasing 50 acres of land having predominately Barnes-Aastad soil adjacent to Swan Lake about ten miles northeast of Morris. This **Swan Lake Research Farm** was the site of much of the early soil erosion research that soon established the Soils Lab's reputation as a national leader in soil and water conservation research. Recently, an adjoining 80 acres of land was purchased by the Barnes-Aastad Association to support the expanding research program of the Soils Lab.

A similar group, the **Eastern South Dakota Soil and Water Research Farm, Inc.**, provides support for our field research on a range of agricultural problems in eastern South Dakota. They currently own an 80-acre research farm near Brookings, South Dakota, where we conduct cooperative research with the USDA-ARS Northern Grains Insects Laboratory and South Dakota State University.

Since the Lab's conception in the early 1950's, the research staff has grown from one Soil Scientist and one Agricultural Engineer to its current staff of eight scientists supported by post-doctorate research associates and support scientists covering a range of disciplines.

THE WINDS OF CHANGE

Since the last NCSCRL Research Planning and Review Conference in 1991, several factors have come into play to impact our immediate and long-term research program.

1. GPRA

   More than any other factor, the Government Performance and Review Act of 1993 (GPRA) is causing the NCSCRL to shift to a slightly different paradigm. The GPRA essentially requires that our research be outcome-based and responsive to customers' needs. Our research program has always been oriented toward either solving production/environmental problems, or providing component knowledge necessary to achieve a solution.

   In the past, this knowledge was often gained without the ultimate customer being intimately involved in the process. As a result, research results often needed modification before they met the needs of our customers.

   GPRA will continue to challenge many of our traditional ways of thinking, both scientifically and administratively. The NCSCRL has initiated several efforts involving farm managers and crop consultants as active participants in designing and conducting research. While these cooperative efforts must logistically be somewhat local, they must serve as models for regional and/or national efforts. Examples of such efforts are (1) the Farmbook prototype Information Management System software developed with intimate involvement of Minnesota and South Dakota farmers, (2) the FarmWin (windows version of Farmbook) being developed with private industry via a CRADA (Cooperative Research and Development Agreement), (3) a Nitrogen Management component for FarmWin being developed through on-farm research, and (4) a multi-state Bio-Economical Weed Management software being tested via on-farm trials. Several other initiatives are being considered.

   In addition, cooperative research is on-going with agricultural chemical and plant seed companies, other ARS Labs, NRCS and state universities, and several international institutions.

2. Budget limitations.

   Faced with a flat budget and increasing operating costs, we have chosen to maintain strong resource support for eight permanent scientists rather than a lesser degree of support for our original capacity of 10 scientific positions. The

immediate effect of this has been the loss of two scientist positions and their attending programs in the past five years. The AGNPS effort (Agricultural Non-Point Source pollution model) is scheduled to be transferred from the Morris Laboratory to the ARS National Sedimentation Laboratory in Oxford, MS in April, 1996. The NRCS has generously supported the development of AGNPS and has been instrumental in providing local temporary scientific leadership the past year to advance the development of and facilitate the transfer of AGNPS from Morris to the Sedimentation Lab.

There is an urgent need to add a soil scientist with a microbiology background to the staff to complement our increased research in tillage/residue/carbon and nutrient cycling. There is also an urgent need for permanent specialized support scientists, especially to serve the whole lab in systems engineering and systems integration.

3. South Dakota Cooperation

The NCSCRL has historically retained a strong presence in South Dakota, initially by stationing 3-4 scientists at Brookings, by conducting research at the Eastern South Dakota Soil and Water Research Farm in Madison, SD (leased by the NCSCRL from the Eastern South Dakota Soil and Water Research Farm, Inc.), and by cooperating with the ARS Northern Grain Insects Laboratory in Brookings and the Plant Science Department of South Dakota State University. Over the years, the scientific positions were phased out, and the research farm moved from Madison to Brookings. The full-time technicians stationed at the farm were not replaced when they retired. We maintained field research in Brookings, but on a limited scale.

The ARS Northern Grain Insects Laboratory recently added a soil scientist to their staff, and costs of operating the Eastern South Dakota Research Farm are being shared by our two locations. As a result, we expect to maintain, or even increase, our cooperative efforts in South Dakota.

4. Administrative Consolidation

The retirement of two full-time administrative support personnel allowed an arrangement wherein some administrative functions are being shared with ARS personnel in St. Paul. This arrangement is working very well, and the cost savings has been re-directed to research.

5. Laboratory Addition

Work is almost completed on a 6,300 sq. ft. addition to our laboratory. The main feature is a conference room that will facilitate various kinds of scientific meetings and technology transfer activities. Vacated space in the current building will be remodeled to provide urgent laboratory and other space needs.

LABORATORY MISSION

The new mission of our Laboratory reflects our response to GPRA, the maintenance of America's agricultural productive capacity, and the preservation of our natural resources.

The mission of the NCSCRL is to develop and transfer new knowledge and technologies for sustainable agriculture in northern climatic regions that protect natural resources and the environment.

Preamble

The North Central Soil Conservation Research Laboratory (NCSCRL) was originally established in Morris, Minnesota, to conduct research on various agricultural problems in the transitional subhumid zone of the United States. Physiographically, this included the Red River Valley of Minnesota and North Dakota and extended down through western and south central Minnesota and into north central Iowa, and southeastern South Dakota. In response to increasing public concerns over the environmental impact of intensive agricultural practices, the NCSCRL has since expanded the scope of its research to include environmental concerns with cooperative research that spans the globe.

The mission of the NCSCRL is an integral part of the ARS mission to provide American citizenry with a safe and dependable supply of food and fiber while protecting our natural resources and reducing economic and environmental risk to consumers and farmers.

Naturally occurring challenges specific to the NCSCRL mission include (1) variable soil types within a farming/field unit that preclude uniform management, (2) poorly distributed and intensive precipitation that causes water runoff and soil erosion as well as plant growth stress, (3) temperature extremes causing problems ranging from deep soil freezing to heat/water stress in growing crops, and (4) weed/pests management pressures that cause economic and environmental concerns.

Superimposed on these natural challenges are (1) conventional management practices that often result in nutrient/chemical accumulation in ground and surface water sources, and (2) lack of a methodology to integrate and apply research data to solve problems at the farm level in an effective and timely manner.

The mission of the NCSCRL is accomplished through a series of field, greenhouse, growth chamber and laboratory studies in working cooperation with sister ARS laboratories, various state universities and agricultural experiments stations, action agencies such as the NRCS, private entities such as crop consultants, chemical/machinery companies, plant breeders, and through on-farm trials and farmer involvement.

In accordance with increasing demands from society in general and farm managers in particular, the NCSCRL tailors its basic research effort to provide data for the development phase of research application to solve problems at the farm level.

CRIS STRUCTURE

To accomplish our new Laboratory Mission, and to accommodate decreased research efforts on soil erosion and soil compaction along with increased efforts in farming systems research, the Laboratory's research program has been re-organized into the following CRIS Projects:

1. ENVIRONMENTAL PLANT PHYSIOLOGY -- "Physiological Approaches to Maximize Production Efficiency and Minimize Production Risks."
2. SOIL MANAGEMENT -- "Enhancement of Soil Properties Through Soil Management."
3. RESIDUES -- "Residue Impacts on Soil Surface Processes Affecting Soil and Air Quality."
4. CROP MANAGEMENT -- "Identification of Management Thresholds for Crops in Cold Climates."
5. TECHNOLOGY -- "Integrated Systems Development and Engineering."

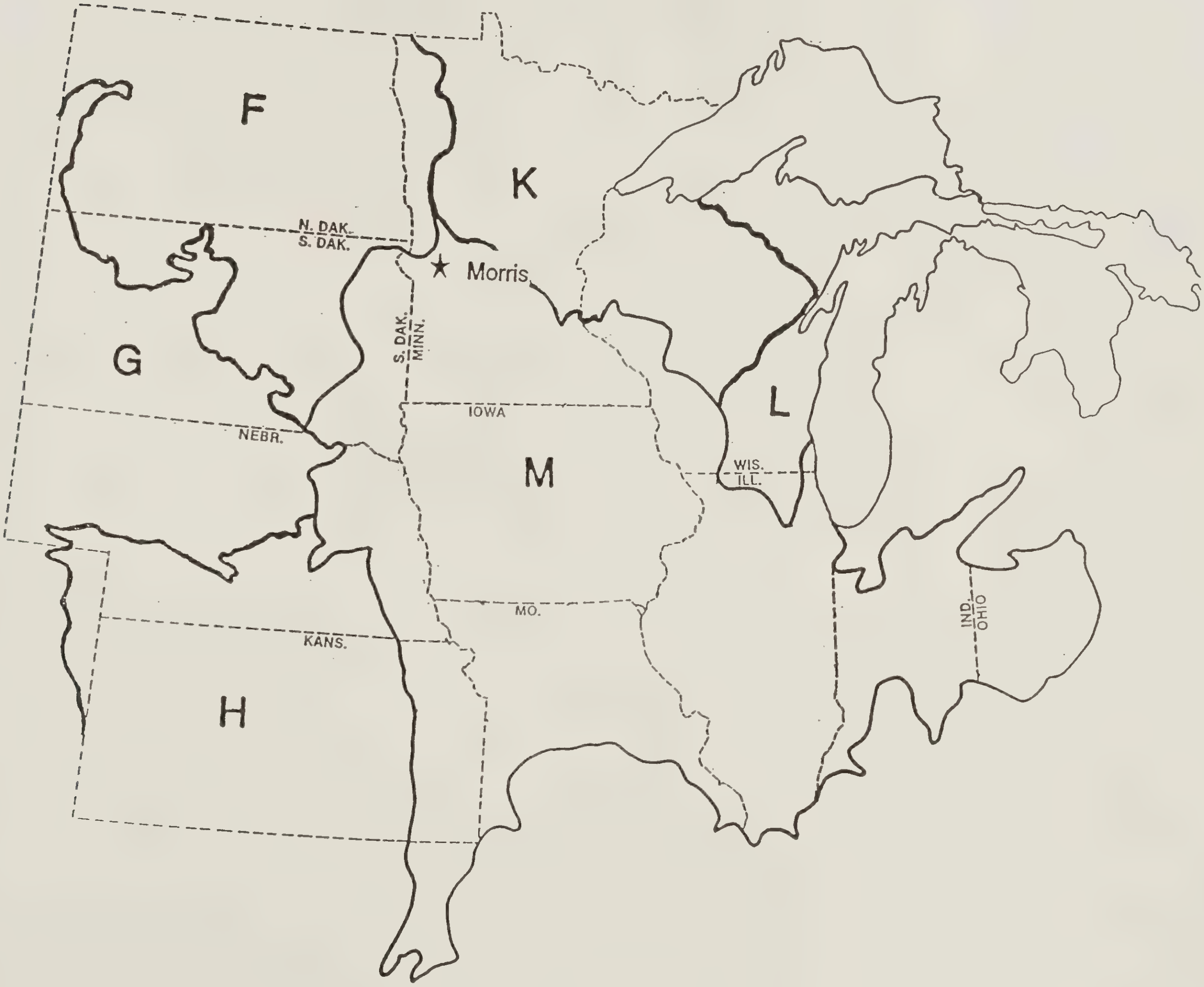
A brief summary of each of these CRIS Projects is contained in the following sections.

Table 1. Share of U.S. Total Production by Minnesota, North Dakota, South Dakota, Iowa and Wisconsin in 1993.

(Agricultural Statistics, USDA, 1994)

CROP	%
Barley	44
Corn	35
Hay	29
Oats	58
Potatoes	14
Soybeans	25
Sugar Beets	32
Sun Flowers	83
Wheat (All Wheat)	22

Figure 1. Land Resource Regions of the Midwestern U.S. (Agriculture Handbook 296. USDA. 1965)



F - Northern Great Plains Spring Wheat
G - Western Great Plains Range and Irrigated
H - Central Great Plains Winter Wheat and Range
K - Northern Lake State Forest and Forage
L - Lake States Fruit, Truck and Dairy
M - Central Feed Grains and Livestock

PHYSIOLOGICAL APPROACHES TO MAXIMIZE PRODUCTION EFFICIENCY AND MINIMIZE PRODUCTION RISKS

Investigators: Mark Westgate, Lead Scientist
Frank Forcella
Alan Olness
Donald Reicosky

TITLE: Physiological Approaches to Maximize Production Efficiency and Minimize Production Risks

OBJECTIVES:

The proposed research seeks to gain fundamental understanding of key physiological mechanisms that control plant development in environments typical of the northern Corn Belt. Specific Objectives are: to demonstrate interactions between genotype, soil physical/chemical characteristics, and climate for nutrient acquisition efficiency; to determine the physiological basis for deleterious effects of environmental extremes on seed formation and development; to determine the impact of conservation tillage on canopy photosynthesis and evapotranspiration under droughty conditions; and to develop a reliable methodology to distinguish dormant from non-dormant seeds.

NEED FOR RESEARCH:

Risks to producers result largely from weather- and pest-related stresses that constrain crop development and decrease crop quality. While numerous genotypes for each major crop grown in the northern Midwest states are available to producers, specific genotypic characteristics best suited to maximize production efficiency and minimize production risks for a given set of soil and climatic conditions are not easily identified. The economic impact of weeds on agricultural producers in the US is estimated at $15 billion per year. Information on weed seed dormancy used in conjunction with bioeconomic weed management decision aids can reduce weed control costs by 67% while maintaining high crop yield. A quick and effective means of distinguishing viable/non-viable and dormant/non-dormant weed seed in soil samples, however, is lacking. Over 40% of our nation's agricultural land is subject to intermittent drought. The high vulnerability of seed formation is particularly significant for US agriculture, because in most cases, seeds are the economically important part of the crop. A decrease in photosynthesis during the critical flowering/pollination period can decrease seed set, but the potential of conservation production systems to stabilize canopy photosynthetic capacity in dry years has not been evaluated. Phytohormones also are known to be involved in the seed formation process. However, a major knowledge gap exists concerning their role in controlling flower/seed abortion during drought. Soybeans produced in Northern growing areas are often discounted because they are relatively low in protein and oil content. Temperature is known to alter seed growth rate and composition, but the physiological mechanisms underlying this effect are not understood. This knowledge is essential to develop soybean genotypes having stable seed composition across environments and capable of accumulating high protein levels under cool growing conditions.

PAST RESEARCH:

Dr. Forcella documented seedbank dynamics in varying tillage systems for important weed species, and seedling emergence from such seedbanks has been related to environmental variables in a model (EMERG) to determine optimum time for seed bed preparation. Dr. Forcella has also determined the microclimate factors that govern secondary dormancy in select weed species. Dr. Olness, in collaboration with other ARS scientists, developed a model for macro-nutrient accumulation by maize. He has demonstrated synchrony of nutrient accumulation patterns varies with planting date, and has correlated nutrient accumulation with soil- and air-thermal energy intensity (TEI). Related field studies show clear tillage-hybrid-N fertility interactions on post-emergent mortality and barrenness and tillage effects on soil aeration. Dr. Reicosky developed field techniques for measuring canopy photosynthesis, evapotranspiration, and soil respiration in remote locations. Dr. Reicosky's

portable chamber technique has made it possible to examine short-term carbon cycling in agricultural production systems, especially in evaluating plant response to tillage. Dr. Westgate developed a multi disciplinary research approach to investigate the effects of plant water deficits on reproduction in corn and soybeans. He showed direct effects of low tissue water potential on the reproductive physiology of corn and soybean and that seed growth is maintained in water-stressed plants by an apparent hydraulic isolation of the seeds from the vegetative plant and a concerted shift in metabolism within the vegetative and reproductive tissues. He has shown seed formation to be limited by low assimilate flux in corn by low cytokinin levels in soybean and high ABA level in wheat. He discovered the response of soybean seed composition to growth temperature was due to a shift in carbon partitioning into protein synthesis within the embryo.

FUTURE RESEARCH:

Distinguishing dormant from non-dormant seeds. Induction of secondary dormancy in non-dormant weed seeds will be examined in artificial microclimates (temp, soil moisture, and temp X moisture). Duration of exposure to these environments will be examined for intensity of induction into dormancy states. Enzyme activities, leachate metabolites, and reflectance characteristics will be evaluated for their efficacy in distinguishing dormant and non-dormant seeds.

Matching genotypes with soil chemical conditions. First, the relative stability (or variance) of both chemical composition and its intensity will be characterized within specific soil mapping units. Second, the relationship(s) between composition and intensity of the available/extractable soil chemistry and relative genotype response will be established. Soils will be sampled in transects across a defined geographic range, extracted for "active" soil chemistry, and variability analyzed according to standard geostatistical procedures. Seed yield, kernel weight, weed competition, and rate of crop development will be analyzed as a function of time, climate, and specific soil chemistry. Data will be evaluated for relationships between genotype and extractable soil chemistry.

Improving Seed Formation during Drought. Involvement of phytohormones (abscisic acid and cytokinins) in determining seed set in maize is not known. We will use standard techniques to quantify the level of these hormones in reproductive tissues during drought. Initial experiments will examine the response of whole ovaries (including pericarp, pedicel, nucellus, egg sac). If significant changes in hormone levels are detected, analysis will shift to individual reproductive tissues. Hormone levels in developing ovaries will be altered intentionally by injecting ABA and/or benzylaminopurine (PAB), a cytokinin analog, into the ear shank subtending the ear as drought stress develops. Changes in hormone level in reproductive tissues will be monitored and correlated to kernel development. We are using a genetic approach, coupled with application of a cytokinin analog, benzylaminopurine (BAP) to determine whether pod abortion limits yield of field-grown soybeans known to vary in level of pod abortion and their responsiveness to BAP. Rates of canopy photosynthesis, soil respiration, and evapotranspiration are determined throughout the growing season to estimate canopy (source) response to altered reproductive load. Pod set, agronomic characteristics, yield, and yield components are determined at harvest maturity.

Relating Temperature and Seed Composition. Recent studies indicate growth temperature altered the partitioning of glycolytic and amino carbon into protein and oil metabolism within the developing seed. This shift in metabolism may reflect a temperature-dependent competition for common substrates at key metabolic "crossroads" between protein and oil metabolism. We will test this possibility using the differential response of key enzymes to temperature, the known response of seed composition in specific soybean genotypes to temperature, and near-isogenic soybean lines for high and low seed protein we have developed. We also are testing the potential of using marker-assisted selection to improve the efficiency of selection for seed protein and oil content.

RESIDUE IMPACTS ON SOIL SURFACE PROCESSES AFFECTING SOIL AND AIR QUALITY

Investigators: Donald Reicosky, Lead Scientist
Michael Lindstrom
Alan Olness
Brenton Sharratt
Mark Westgate

TITLE: Residue Impacts on Soil Surface Processes Affecting Soil and Air Quality

OBJECTIVE:

The general objective is to develop conservation tillage and residue management systems for sub-humid agriculture and glacial till soils. Tillage methods with a range of tillage intensities (conventional, reduced, and no-till systems) and different cropping sequences with emphasis on corn, soybean and wheat will be evaluated for productivity and profitability and their impact on soil, water and air quality. Specific Objectives include: 1. Determine physical/physiological basis for effects of tillage, soil pH, and residue management on soil water, chemical, and CO_2 fluxes from the soil and in the canopy. 2. Determine the effects of residue placement and tillage interactions on turnover of soil organic carbon. 3. Evaluate interactions of crop residue type, amount, and orientation on surface thermal and transport properties in conservation tillage systems. 4. Develop improved measurement techniques for soil respiration and carbon fluxes from different tillage and cropping systems.

NEED FOR RESEARCH:

No-till and other conservation practices are effective in reducing soil erosion. The successful adoption of surface residue management systems requires knowledge of how rapidly the plant residues are decomposed under field conditions with special emphasis on reduced tillage systems. The ability to predict CO_2 flux from agriculture ecosystems is needed for developing accurate carbon cycle models of these production systems. Information is needed on various tillage cropping rotations systems to gain insight into the effect of the climatic change on soil CO_2 fluxes. These systems must be tailored for specific requirements for each of the combinations of tillage methods, soil types, crop systems and crop rotations and different climatic zones.

Residue management goes hand-in-hand with conservation tillage and has a major impact on soil carbon and greenhouse gas emissions, especially CO_2. The interaction of the fertility strategy and developing practical means of increasing soil organic carbon, requires an understanding of crop rotations and cropping systems that maximize return of residue to the soil. Residue on the soil surface generally impedes energy transport across the soil-atmosphere interface. Little is known about the impact of residue on overwinter movement of chemicals and the physical properties of residue that influence water and heat flow. A thorough understanding of properties which govern decomposition, water retention, and thermal diffusivity will aid in identifying crop types and cultivars compatible with regional climatic limitations.

Retention or sequestration of carbon in agricultural ecosystems requires an understanding of the complex carbon:nitrogen (C:N) ratio, water and temperature interactions on microbial decomposition of crop residues. Relationships on the quantity and quality of nitrogen provided by the crop residues, cover crops and legumes, and the previous year's crop play an vital role. An integrated research program serves as a basis for developing highly efficient, cost-effective systems of tillage and conservation practice for control of erosion and soil carbon.

PAST RESEARCH:

Direct influence of residue and tillage on CO_2 flux is varied and highly interactive. Tillage intensity and type affect CO_2 loss from soil. Soil fracturing caused by tillage aids CO_2 loss from and oxygen

entry into the soil. Conservation tillage tools caused less CO_2 loss and improved residue management when compared to moldboard plowing. Residues on the soil surface not only affect gas fluxes, but generally suppress soil temperatures in the spring. Soil temperature is affected by heat and water transfer processes through residue. These transport properties are affected by straw color, which in turn affects radiation balance.

Mineralization is also impacted by residue management. Soil carbon and nitrogen cycles are intimately related to the processes of mineralization and immobilization. The net amount of immobilization which accompanies crop residue decomposition is a major factor in determining the N fertilizer requirement for the next maize crop. Soil freezing effects nitrate movement and early season crop production. However, other consequences of tillage that may affect soil, water and temperature are not easy to predict. Work on CRP land returned to cultivation has shown tillage-related changes in soil structural properties which affect soil erosion, infiltration, compaction, and crop production.

FUTURE RESEARCH:

Agricultural sustainablity implies achieving desired levels of agronomic productivity while maintaining or enhancing soil and environmental qualities. The effects of conservation tillage and residue interactions on greenhouse gas fluxes and soil carbon will be evaluated. The physical attributes of the residue as they affect the transport of energy and mass and promote soil stability will be studied. The dynamic nitrogen interactions in high residue cropping systems will be related to carbon and nitrogen cycling in agri-ecosystems. Optimal sequences of various crops and tillage residue management systems to maximize water and nutrient use efficiency for economic sustainability, environmental and groundwater quality will be determined.

Field research interacting with greenhouse and laboratory research will be used to evaluate and develop methodologies to determine the effect of crop differences on residue decomposition with emphasis on the C:N ratio. The effect of tillage and residue management on the soil physical conditions will be determined on corn and soybean under various tillage systems including no-till, combination chisel plow, roto-till, and moldboard plow systems. Soil physical factors studied will include soil water content, infiltration, temperature, bulk density, soil strength, compaction and surface roughness. Management practices that vary residue amount, orientation, height and density on the soil surface will be evaluated for energy transfer. Chemical tracers applied to residue treatments will be used to track overwinter movement of nitrate-N. Physical properties of residue impacting heat and water transmission will be assessed using a controlled temperature chamber.

ENHANCEMENT OF SOIL PROPERTIES THROUGH SOIL MANAGEMENT

Investigators: Michael Lindstrom, Lead Scientist
Frank Forcella
Alan Olness
Donald Reicosky
Brenton Sharratt
Ward Voorhees

TITLE: Enhancement of Soil Properties through Soil Management

OBJECTIVE:

(1) Determine the effects of soil tillage intensity on soil physical and chemical properties that have developed under ten years of sod culture (CRP), and (2) determine the effects of soil tillage intensity and residue management on soil properties affecting water infiltration, crop production, soil erosion, weed emergence, biological activity, gaseous exchange, and chemical transport.

NEED FOR RESEARCH:

Approximately 14.8 million hectares or eight percent of the cropland in the U.S. has been enrolled in CRP. CRP contracts will have expired on 8.9 million hectares by 1997. As CRP contracts expire, landowners will be required to make many decisions, but recent surveys indicate that much of this land will be returned to cropland if CRP contracts cannot be renewed. As global concerns about soil degradation increase, landowners will be directed toward maintaining the environmental benefits of CRP, even on land returning to crop production. This can be accomplished if tillage and cropping practices promote the sustainability of soil quality.

Topographical depressions in the prairie pothole region threaten the quality of ground and surface waters owing to depression-focused recharge. Depression-focused recharge occurs primarily in the spring as a result of overland flow above a frozen subsoil. Downslope transport of solutes is likely; however, the extent of overwinter vertical and lateral movement of solutes is unknown. Chemical transport in soil is partly dependent on flow paths within the soil. Preferential flow paths can result in rapid movement of chemicals through the soil profile and into ground water systems. The stability of these flow paths during winter, as well as the impacts of freeze/thaw cycles on preferential transport of chemicals is unknown. The soil physical properties at the time of freezing can impact mechanical forces occurring in the soil matrix. Thus, understanding the role that freezing and thawing have on soil consolidation and density may lead to identifying soil management practices that promote structural development and ameliorate compacted soils.

Soil aeration is a complex function of precipitation, infiltration, soil composition and particle size distribution, evapotranspiration, soil water distribution, soil porosity, gas permeability, and soil bulk density. Efforts are needed to evaluate tillage-induced changes in soil porosity as they effect 0_2 and CO_2 exchange for both short-term and full-season effects.

PAST RESEARCH:

Interactive effects of cyclic freezing and thawing and freeze-drying on aggregate stability of surface soil aggregates were determined. Freeze-drying created instability in aggregates. Stability appears to be a function of initial water content, aggregate size, and freeze-thaw history. Aggregate breakdown increased linearly with water content and curvilinear with aggregate size. Minimizing the occurrence of freeze-drying and raindrop impact on the soil surface will reduce aggregate breakdown and erosion in the winter.

Improved soil structure and continuity of soil macropores that developed during CRP are best maintained with no-till management. The no-till treatment and undisturbed grass had no water runoff or soil loss after 12.5 cm of rainfall was applied in two events at an intensity of 6.25 cm hr^{-1}; whereas, the moldboard and chisel plow exhibited considerable water runoff and soil erosion. The continuity of soil macropores in the no-till management system was maintained through four years of crop production, even after all remnants of the grass biomass had disappeared. No-till management was shown to be a viable option when highly erodible lands are returned to crop production.

Progress has continued on AGNPS and the WEPP-grid model. A routine was developed to model the interaction of snowdrifting, snowmelt, and frost formation and their effects on soil erodibility and subsequent erosion. Other modifications to the single-event model of AGNPS as requested by NRCS have been completed. AGNPS version 5.00 was released May 30, 1995. A continuous simulation version of AGNPS is being developed. The ARS National Sedimentation Laboratory in Oxford, MS will assume leadership for this effort after April 1996.

FUTURE RESEARCH:

Two CRP sites have been selected for study, one in Minnesota and one in South Dakota, representing cropping systems in the northern Corn Belt (corn-soybean) and in the northern Great Plains (wheat-fallow). Post-CRP management variables at the two locations include undisturbed CRP sod, tillage intense system, conservation compliance tillage system, and no-till. Additional studies will be conducted on already established cropping and tillage management plots at the Eastern South Dakota Soil and Water Conservation Research Farm, Brookings, SD, with varying levels of tillage, rotation, and agricultural chemical inputs. These studies will provide information on the effect of soil properties such as soil organic matter, soil structure, structural stability, and soil porosity on infiltration, aeration, plant available water, biological activity, crop production, and soil erosion. Changes in soil porosity and pore stability in response to tillage and freezing and thawing will be ascertained using canopy gas exchange chamber and controlled temperature chamber techniques. Reconsolidation of the tilled zone from natural weathering forces will be attributed to changes in soil density within the depth of tillage. Solute movement in ridges created by tillage and along contours in depressions will be determined with bromide tracers along with soil physical properties important to solute transport.

IDENTIFICATION OF MANAGEMENT THRESHOLDS FOR CROPS IN COLD CLIMATES

Investigators: Frank Forcella, Lead Scientist
Michael Lindstrom
Alan Olness
Donald Reicosky
Ward Voorhees
Mark Westgate

TITLE: Identification of Management Thresholds for Crops in Cold Climates

OBJECTIVES:

Our primary objectives are to integrate the biological and physical aspects of crop environments, examine the utility for crop management of new knowledge gained by integration, and if useful, extend this knowledge to other scientists, extension educators, crop consultants, producers, and the general public. More specifically, we plan to define agronomically meaningful thresholds at which producers and crop consultants can make important decisions for crop management and soil conservation with greater ease and more confidence.

NEED FOR RESEARCH:

National research and education priorities for USDA, as stated in the 1995 Farm Bill, emphasize integration of the biological, physical, and social sciences. These priorities were implemented to better address current and future agricultural research problems as "systems," but without compromising the important contributions of disciplinary research. Our proposed research attempts to integrate the biological and physical aspects of crop environments so that relevant information may be more effectively probed by the social components of crop production, that is, crop managers and management economics.

Although research conducted by members of our team encompasses sites across the nation and world, our primary region of responsibility is the North Central United States. The brief growing season in this area places timeliness demands on producers. They must exercise management options quickly and effectively with little chance for corrective measures. Thus, it is especially important that their decisions be based on current and reliable information. Obtaining, integrating, and interpreting such information, however, is a recognized constraint for producers and consultants.

The decisions made by producers often are triggered by "thresholds" involving agronomic factors such as soil water, temperature, nutrients, organic matter, and structure; crop type, density, and residue; pests; etc. Examples of these thresholds might include: (a) if soil organic matter is high, use more soil-applied pesticide; (b) if temperature is below 10 C, delay corn planting; and (c) if soil is compacted, till. Most thresholds are derived from qualitative observations; sometimes they are semi-quantitative, as with soil temperature and planting dates; and occasionally quantitative evaluations drive decisions, such as soil tests and fertilizer recommendations. Whatever the case, the bases, outcomes, and interrelationships of the relevant agronomic factors that play roles in these decisions typically are poorly defined. A simple but good example of this problem is the relationship between soil tests and fertilizer recommendations. Although the relationship is very useful for making crop management recommendations, it does not yet account for N mineralization in field soils after the soils were sampled in autumn or spring. The timing and extent of soil N mineralization in spring, early summer, and autumn can have profound effects on N fertilizer requirements. Furthermore, as cover crops become more accepted by producers in the near future, an understanding of their differential contributions or "credits" to the pool of soil mineral N need documentation.

Another excellent example is the fundamental decision to till soil. Although there are many factors that interact to influence a producer's decision to till soil, two important agronomic factors are weeds

and soil compaction, and an important environmental factor is preservation of soil organic matter. We must develop objective thresholds regarding weeds, soil organic matter dynamics, shallow and deep soil compaction, and seedbed tilth, temperature, and water contents that justify tillage in landscapes with varying propensities of soil erosion. Furthermore, we must combine these separate categories of thresholds into user-friendly expert systems that provide producers, consultants, and action agencies with readily accessible means to help make informed decisions.

PAST RESEARCH:

Members of our team have recently established the following generalities or principles: (a) Oriade and Forcella determined that the monetary value of site-specific weed management is very dependent upon the nature and level of variability of the weeds being managed. (b) Olness and Reicosky found that cover crop development and crop N use follow patterns and principles of thermodynamics, and that crop environments can be managed to optimize these relationships. (c) Reicosky and Lindstrom perfected techniques for measuring gas exchange to such an extent that highly dynamic gas fluxes can be detected and ascribed to various crop management options. (d) Forcella found that computer-based decision aids that account for high levels of biological understanding of weeds and crops aid producers in making more money, use less herbicide, and maintain good weed control and crop yields. (e) Westgate and Olness showed that a thorough understanding of crop-water relationships permitted elimination of late-season irrigation of field corn without affecting yields, resulting in annual energy savings of up to one million dollars in Minnesota. This contributed to revision of the primary Minnesota extension bulletin on irrigation scheduling. (f) Voorhees and Lindstrom proved that the effects of wheel traffic on plants and soil can be detrimental or beneficial, depending upon soil type and seasonal weather. Complexity of interactions among soil, crops, machinery, and weather created the demand for an expert system, such as COMPAC, which was developed under the direction of Voorhees.

FUTURE RESEARCH:

We plan to conduct integrative and cross-disciplinary research on tillage and tillage systems; crops and cropping systems; weeds and weed management systems; and nutrients and fertilizer management systems. Our goal is to integrate our agronomic, environmental, and economic results into user-friendly forms of information that provide producers, consultants, and action agencies with readily accessible means to help make informed decisions.

INTEGRATED SYSTEMS DEVELOPMENT AND ENGINEERING

Investigators: Sam Alessi, Lead Scientist
Frank Forcella
Alan Olness
Donald Reicosky
Ward Voorhees
Mark Westgate

TITLE: Integrated Systems Development and Engineering

OBJECTIVE:

1) To design efficient systems integration and development processes for creating software-driven systems that integrate agronomic and ecological knowledge yet preserve stakeholder quality, relevance and usability. 2) To develop a user-oriented whole-farm Management Information System (MIS) in a manner that is scientifically accurate, cost effective, timely, relevant and results in a system that is used.

NEED FOR RESEARCH:

The ARS 6-year Program Plan (1992-1998) and the Government Performance and Review Act of 1993 (GPRA) express a need in the agricultural research community to produce integrated information management products that can be transferred effectively to the marketplace. This goal requires a collaborative effort between science (which seeks new knowledge) and engineering (which limits its concerns to pragmatic issues). Currently, the agricultural research community, including ARS, relies mainly on traditional academic processes involving individual freedom, science experiments and strivings toward new technologies (simulation models, expert systems, GPS, GIS, etc.) to perform both science (research) and engineering (development) tasks.

This often creates a problematic situation for integrated systems development, as manifested by unmet promises, missed deadlines, high maintenance and support costs, poor documentation and dissatisfied users. The central problem is a mismatch between agriculture's desires for integrated systems products and the methods used to produce these products. The solution is to research the best engineering processes that allow integration, ensure scientific correctness, improve overall quality, increase schedule predictability, reduce costs and maintain user-oriented relevance.

PAST RESEARCH:

Research into whole farm information architectures suitable for usability and research integration has been conducted at the NCSCRL in Morris since 1989. This research is represented by the computer software products entitled Farmbook and FarmWin. Farmbook was released in 1995 and has since been mailed to over 580 farmers, 100 researchers and eight foreign countries including Canada, Spain, Mexico, Brazil, Hungary, Switzerland, Lithuania and Peru. FarmWin is a commercial software product being developed with private industry within a Cooperative Research and Development Agreement (CRADA) and is scheduled to be released late 1996.

This work would not have been possible without our research in engineering process. For example, it is now very clear that the users (farmers) must be involved throughout the development so that the system remains relevant to real farm needs. Numerous other process elements have been incorporated, all of which are critical to the final product. Overall, this process infrastructure helped us reduce research innovation cycle time to four years for Farmbook and we expect approximately 18 months for FarmWin.

FUTURE RESEARCH:

This CRIS will perform research aimed at developing R&D processes that ensure end-product desires are met. It will test the effectiveness of the new processes, invented locally and gathered from the literature during the ongoing construction of a farm management information system for use on farms.

An attractive beginning point is the application of specific processes embodied in a strategy entitled by the Software Engineering Institute (SEI) as Maturity Modeling. This approach has been developed specifically for improving software and systems engineering processes and is attractive since it was derived from data collected across many R&D organizations and can be applied in an evolutionary manner at any point within a project.

The product to be developed will continue the ongoing work of the Farmbook/FarmWin project. Potential new features and extensions to the systems are documented in a requirements database. Overall, we expect that the integration work will partition into three areas; general usability and integration, analytical tools (weather analysis, on-farm trial analysis, multi-objective, neural network, fuzzy logic decision making and general statistical processing) and traditional research features (weeds, nutrients, insects, water, temperature, etc.). Modules will either be developed in-house or will be obtained from other sources. Criteria for the selection of various modules will be imbedded within the engineering processes used. Collaborative efforts are already being planned in the areas of nutrient and weed management. Critique of outside sources will involve mathematical, architectural and documentation reviews. Of critical importance for any collaboration is an unified vision and clarity of roles, human interfaces, expectations and real costs.

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NORTH CENTRAL SOIL CONSERVATION RESEARCH LABORATORY

USDA -ARS

MORRIS, MINNESOTA

(Authors who were located at the Research Laboratory at the time of publication are underlined)

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